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Methodology for Developing Preliminary Remediation Goals for the OU 7-13/14 Subsurface Disposal Area

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ABSTRACT

This report presents methodology for developing preliminary remediation goals for Operable Unit 7-13/14. Operable Unit 7-13/14 comprises the comprehensive remedial investigation and feasibility study for Waste Area Group 7 at the Idaho National Engineering and Environmental Laboratory. The primary focus of investigation is the Subsurface Disposal Area, a radioactive waste landfill located within the Radioactive Waste Management Complex. Contaminants in the landfill include hazardous chemicals, contact- and remote-handled fission and activation products, and transuranic radionuclides.

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ACRONYMS

ABRA	Ancillary Basis for Risk Analysis
COC	contaminant of concern
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
K_d	partition coefficient
OU	operable unit
PRG	preliminary remediation goal
RAO	remedial action objective
RI/BRA	remedial investigation and baseline risk assessment
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SVR	soil vault row
TBD	to be determined

Methodology for Developing Preliminary Remediation Goals for the OU 7-13/14 Subsurface Disposal Area

1. INTRODUCTION

This document presents methodology for determining preliminary remediation goals (PRGs) for the Operable Unit (OU) 7-13/14 feasibility study. The feasibility study will evaluate remedial alternatives for the Subsurface Disposal Area (SDA) within the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL). The map in Figure 1 shows the location of the RWMC within the INEEL. Figure 2 provides a detailed map showing locations of the SDA burial pits, trenches, and disposal sites.

Contaminants in the SDA include hazardous chemicals, contact- and remote-handled fission and activation products, and transuranic radionuclides. The *Ancillary Basis for Risk Analysis of the Subsurface Disposal Area* (Holdren et al. 2002) estimates cumulative human-health and ecological risks associated with the SDA. The Ancillary Basis for Risk Analysis (ABRA) concludes that contaminants within the SDA pose unacceptable long-term risks to human health and the environment.

Preliminary remediation goals are initial cleanup goals (1) that are protective of human health and the environment and (2) that comply with applicable or relevant and appropriate requirements. These initial cleanup goals will be established in the feasibility study for the purpose of evaluating remedial alternatives. Preliminary remediation goals for OU 7-13/14 will be expressed as risk-based concentrations or as technology performance objectives. Risk-based concentrations are contaminant concentrations in specific media (e.g., waste and soil). Technology performance objectives are action-specific measures to satisfy remedial action objectives (RAOs). Examples of technology performance objectives are infiltration rates and contaminant release rates that can be achieved by containing or treating the waste. Preliminary remediation goals will be developed to identify and evaluate remedial alternatives that can meet OU 7-13/14 RAOs. This report describes how those PRGs will be developed.

As specified in the *Second Revision to the Scope of Work for the Operable Unit 7-13/14 Waste Area Group 7 Comprehensive Remedial Investigation/Feasibility Study* (Holdren and Broomfield 2003), RAOs identified in the *Preliminary Evaluation of Remedial Alternatives for the Subsurface Disposal Area* (Zitnik et al. 2002) will be applied to the feasibility study. The RAOs are listed below:

- Limit cumulative human-health cancer risk for all exposure routes to less than or equal to 1E-04
- Limit noncancer risk for all exposure routes to a cumulative hazard index of less than 2 for current and future workers and future residents
- Inhibit migration of contaminants of concern (COCs) into the vadose zone and the underlying aquifer
- Inhibit exposures of ecological receptors to COCs in soil and waste with concentrations greater than or equal to 10 times background values, resulting in a hazard quotient greater than or equal to 10
- Inhibit transport of COCs to the surface by plants and animals.

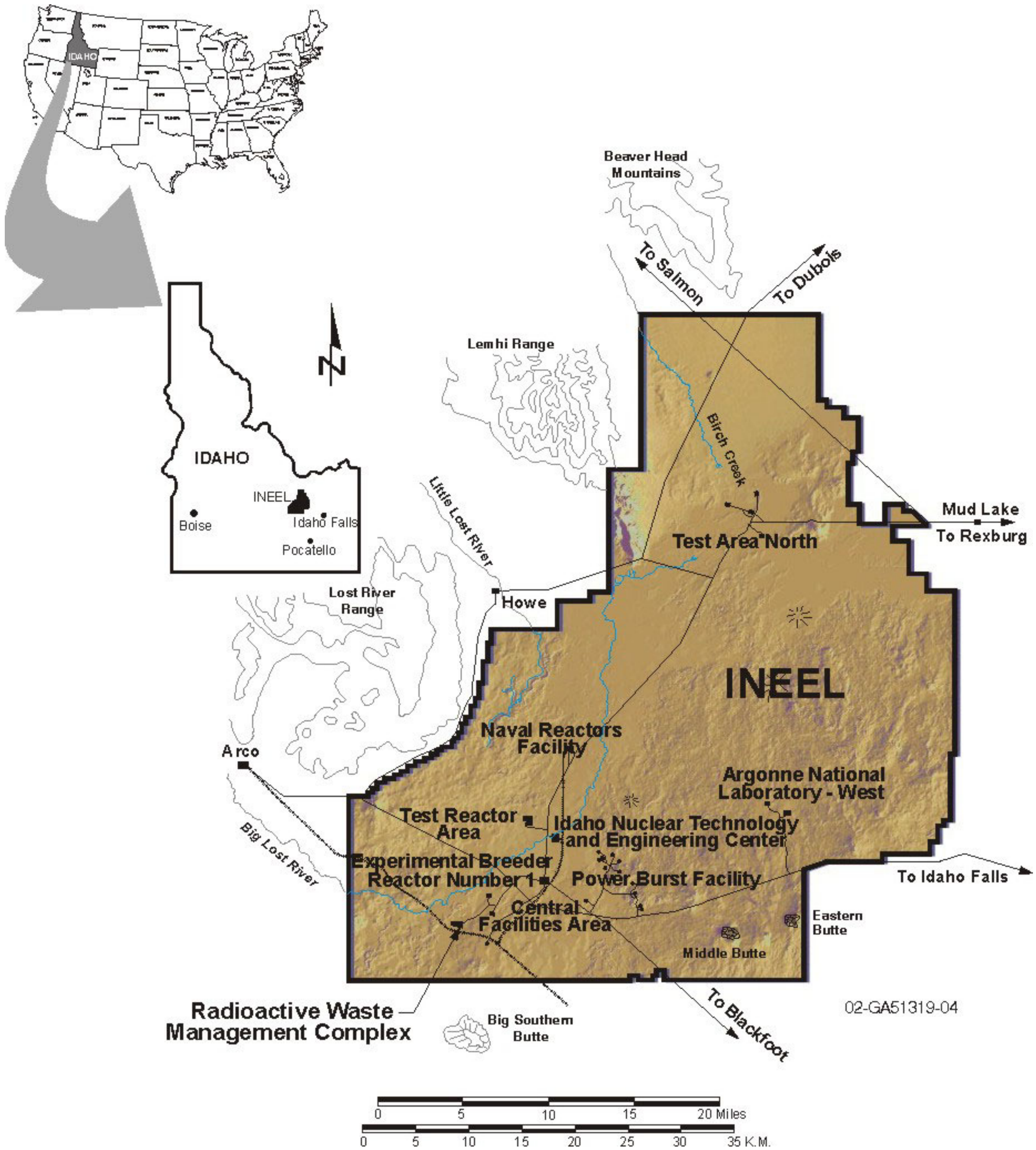

Figure 1. Map of the Idaho National Engineering and Environmental Laboratory showing locations of the Radioactive Waste Management Complex and other major facilities.

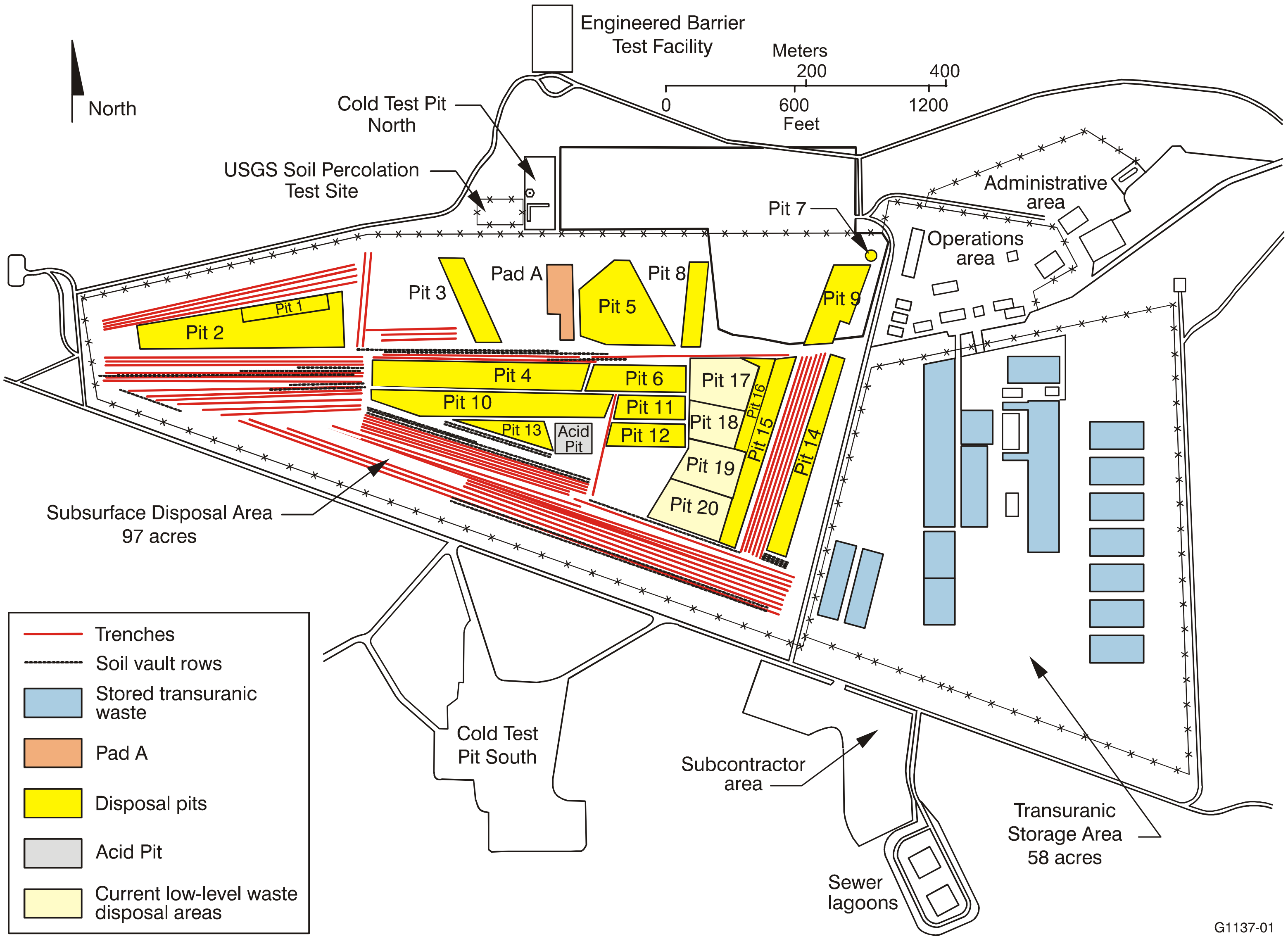

Figure 2. Map of the Subsurface Disposal Area within the Radioactive Waste Management Complex.

1.1 Purpose

The purpose of this report is to present a methodology for developing PRGs for the SDA and to test the methodology with a representative suite of test cases to support the feasibility study. The report does not develop PRGs but does describe how risk-based concentrations and technology performance objectives will be calculated for the SDA. The feasibility study will use PRGs for detailed and comparative analysis of remedial alternatives.

1.2 Overview

Considerable information is available about the radiological and hazardous contaminants buried in the SDA and their fate and transport, as documented in the ABRA (Holdren et al. 2002), inventories of radiological and other contaminants buried in the SDA, and other documented sources of information. This information will be used to support development of the OU 7-13/14 comprehensive remedial investigation and feasibility study under the Comprehensive Environmental Response, Compensation, and Liability Act (42 USC § 9601 et seq., 1980). Preliminary remediation goals generated by this methodology will be used to evaluate remedial alternatives in the feasibility study.

Initial work to develop the feasibility study (e.g., developing this methodology) is already under way. Enforceable deadlines for delivery of the draft remedial investigation and baseline risk assessment (RI/BRA) and the draft feasibility study to the Idaho Department of Environmental Quality and the U.S. Environmental Protection Agency are August 2006 and December 2006, respectively. Actual PRGs in the feasibility study will be based on the work and results of the future RI/BRA. Contaminants of concern and exposure routes of concern already have been identified. Together, information in the ABRA and the RI/BRA will allow direct development of PRGs. To gain perspective on the magnitude of this task, the ABRA identified 20 COCs, six exposure routes of concern, and 13 source areas (as many as 20 source areas may be defined for the RI/BRA). Therefore, developing, testing, and reaching consensus on PRG methodology are being conducted in advance.

1.3 Scope

This report describes methodology to develop human-health PRGs necessary for evaluating remedial alternatives for the SDA. Human-health PRGs will be developed only for a hypothetical post-100-year residential exposure scenario. The methodology addresses the following:

- Radioactive and nonradioactive COCs estimated to remain in the SDA waste zone at the time remedial action begins. The waste zone is defined laterally by the boundaries of the disposal units (e.g., pits and trenches) and vertically by the first basalt layer beneath the buried waste.

- Exposure scenarios and routes considered in the ABRA. The exposure scenarios are occupational and residential. Exposure routes are groundwater ingestion, inhalation, external exposure, soil ingestion, crop ingestion, and dermal exposure to contaminated water.

Methodology to develop PRGs for ecological receptors (e.g., birds and mammals) is specifically excluded. Ecologically based screening levels will be used as ecological PRGs. The ABRA presents a complete set of relevant ecologically based screening levels, which will be refined as needed and presented in the RI/BRA.

1.4 Brief History and Description of the Subsurface Disposal Area

The RWMC is a restricted-access area located 11.3 km (7 mi) southwest of the INEEL Central Facilities Area in the southwestern portion of the INEEL (see Figure 1). The RWMC encompasses 72 ha (177 acres) and consists of an administrative area, the Transuranic Storage Area, and the SDA landfill.

The original landfill, established in 1952, was called the National Reactor Testing Station Burial Ground. Now part of the SDA, the original landfill covered 5.2 ha (13 acres) and was used for shallow land disposal of radioactive waste. In 1958, the SDA was expanded to 35.6 ha (88 acres). Relocating the security fence in 1988 outside the dike surrounding the SDA established its current size of 39 ha (97 acres). The Transuranic Storage Area (23 ha [58 acres]) was added to the RWMC in 1970. Located next to the east side of the SDA, the Transuranic Storage Area is used to store, prepare, and ship stored transuranic waste to the Waste Isolation Pilot Plant southeast of Carlsbad, New Mexico. The 9-ha (22-acre) administration and operations area at the RWMC includes administrative offices, maintenance buildings, equipment storage, and miscellaneous support facilities. For a detailed map of the physical layout of all RWMC disposal locations and facilities, see Figure 2.

1.5 Document Organization

Sections in this report are organized as follows:

- Section 2 describes the methodology and associated steps
- Section 3 presents several test cases
- Section 4 discusses results of the test cases
- Section 5 provides conclusions about the methodology
- Section 6 lists references cited throughout this report.

2. METHODOLOGY

Preliminary remediation goals will be developed to address a hypothetical future residential receptor located next to the SDA. This methodology begins with land-use assumptions and exposure scenarios for the OU 7-13/14 Waste Area Group 7 comprehensive remedial investigation and feasibility study. These land-use assumptions are listed below, and exposure scenarios are presented in Table 1.

Table 1. Exposure scenarios for the Operable Unit 7-13/14 remedial investigation/feasibility study.

Exposure Scenario	Receptor Location	Exposure Routes	Timeframe	Notes
Residential	INEEL boundary	Groundwater ingestion	100 years 2010–2110	All other exposure routes are incomplete
Future residential	RWMC boundary	Soil ingestion, inhalation, external exposure, crop ingestion, dermal exposure to groundwater, and groundwater ingestion	900 years 2110–3010	RWMC will have passive institutional controls (i.e., existing soil cover and land-use restrictions that are not enforced by a physical presence at the RWMC)
Future residential	RWMC boundary	Groundwater ingestion	9,000 years 3010–12010	Contaminant concentrations in groundwater will be modeled to peak or out to 10,000 years, whichever occurs first
Occupational	On the SDA	Soil ingestion, inhalation, and external exposure	100 years 2010–2110	Baseline activities are to maintain the SDA soil cover and enforce access restrictions. Intrusion will not be quantitatively evaluated for the hypothetical 100-year institutional control period
Future occupational	On the SDA	Soil ingestion, inhalation, and external exposure	900 years 2111–3010	This scenario will not be modeled if risk estimates for the current occupational scenario, which are bounding, are less than 1E-06
Future well-construction intrusion	On the SDA	Soil ingestion, inhalation, and external exposure to contaminated drill cuttings	900 years 2111–3010	This acute well-drilling scenario considers construction of an irrigation well and does not open a route to groundwater that must be evaluated

INEEL = Idaho National Engineering and Environmental Laboratory
RWMC = Radioactive Waste Management Complex
SDA = Subsurface disposal Area

2.1 Land-Use Assumptions

Land-use assumptions include:

- Current and future land use at the RWMC will be limited to industrial applications; agricultural, residential, and recreational uses will be prohibited

- The RWMC will be under active institutional controls for at least 100 years after remediation, ensuring that any intrusion into buried waste is conducted with appropriate protective measures

- After the active institutional control period the RWMC will be under passive institutional controls, such as a cap and deed restrictions with no active presence to enforce land-use restrictions.

Given the above exposure scenarios, PRGs are specific to contaminant, exposure route, and location. To identify locations, the methodology models contaminant release over time to partition contaminant inventories between the waste zone and environmental media at the hypothetical time of remediation. This step produces estimates of contaminant inventories released into the vadose zone and inventories remaining in source areas.

Source areas are discrete waste areas within the SDA. The vertical extent of each source area includes overburden, the waste zone, and underburden down to the first basalt layer. To facilitate contaminant release and transport modeling, a source area might be defined as a single pit or a set of trenches, pits, or soil vault rows (SVRs).

Next, the methodology estimates exposure-route-specific risk using the exposure scenarios in Table 1 for combinations of infiltration and release rates. Preliminary remediation goals are then calculated for each source area. Finally results are compiled by source area, and a combined analysis looking at all source areas is conducted to verify RAOs are met.

These steps are listed below and shown in Figure 3:

1. Identify a site with unacceptable risks

2. Identify COCs

3. Identify exposure routes of concern

4. Identify source areas of concern

5. Estimate quantity of contaminants released from each source area

6. Estimate groundwater risks from released contaminants

7. Estimate quantity of contaminants remaining in source area

8. Estimate risks for each exposure route of concern from each COC for each media of concern for each relevant source area

9. Generate matrix of risk estimates for five release rates and four infiltration rates

10. Develop PRGs for source areas

11. Compile results by source area

12. Conduct a combined analysis for all source areas.

A detailed description of the 12-step methodology is contained in the following subsections.

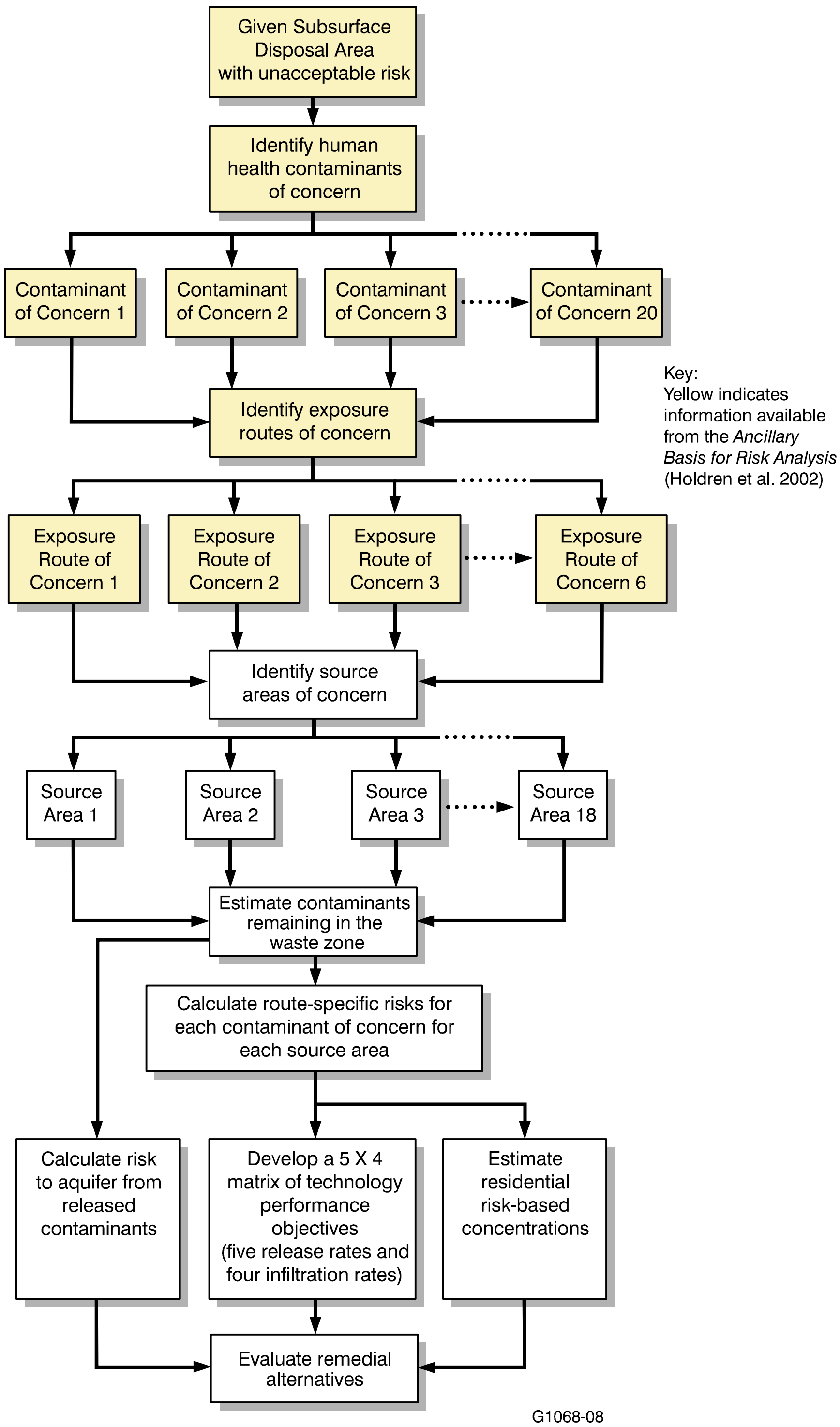

Figure 3. Overall development of human-health preliminary remediation goals.

2.2 Step 1. Identify a Site with Unacceptable Risk

To establish a need for PRGs, the site in question must pose an unacceptable risk. The ABRA explicitly states, "The conclusion of this report is that the Subsurface Disposal Area poses unacceptable long-term risk to human health and the environment."

2.3 Step 2. Identify Contaminants of Concern

Step 2 identifies which contaminants cause the risk (i.e., COCs) and the associated risk threshold. The Second Revision to the Scope of Work (Holdren and Broomfield 2003) identified 20 COCs:

- Sixteen human-health COCs (based on risk criteria of a carcinogenic risk greater than 1E-05 or a hazard quotient greater than or equal to 1 that contributes to a cumulative hazard index greater than 2).

- One potential human-health COC (i.e., Cl-36) based on preliminary modeling results using inventory corrections, which indicate a risk from Cl-36 to be 1E-05. If results are validated, Cl-36 will be identified as a COC.

- Three special-case COCs (plutonium isotopes) to acknowledge uncertainties about plutonium mobility in the environment and to reassure stakeholders that risk management decisions for the SDA will be fully protective.

These contaminants and risk estimates are listed in Table 2.

Table 2. Human-health contaminants of concern and 1,000-year peak risk estimates for a hypothetical future residential exposure scenario.

Contaminant of Concern	Peak Risk	Peak Hazard Quotient
Am-241	3E-05	NA[a]
C-14	6E-04	NA
Cl-36	6E-06[b]	NA
I-129	6E-05	NA
Nb-94	8E-05	NA
Np-237	4E-04	NA
Pu-238	1E-09	NA
Pu-239	2E-06	NA
Pu-240	2E-06	NA
Sr-90	1E-04	NA
Tc-99	4E-04	NA
U-233	3E-05	NA
U-234	2E-03	NA
U-235	1E-04	NA
U-236	1E-04	NA
U-238	3E-03	NA

Table 2. (continued).

Contaminant of Concern	Peak Risk	Peak Hazard Quotient
Carbon tetrachloride	2E-03	5E+01
Methylene chloride	2E-05	1E-01
Nitrates	NA	1E+00
Tetrachloroethylene	NA	1E+00

a. NA = not applicable.
b. Preliminary results from modeling based on inventory corrections indicate Cl-36 risk is 1E-05. If results are validated, Cl-36 will be identified as a contaminant of concern.

2.4 Step 3. Identify Exposure Routes of Concern

Step 3 specifies how the COCs are causing or might cause the risk. This step involves identifying major exposure routes for each COC. This information identifies not only the media of concern (i.e., soil, groundwater, or air) but also how the receptor is exposed (e.g., ingestion, inhalation, or through the skin). The ABRA identifies six exposure routes for three media of concern for human health. The details of this information are provided in Table 3.

Table 3. Exposure routes for human-health contaminants of concern.

Contaminant of Concern	Human Exposure Route(s) of Concern
Am-241	Soil ingestion, inhalation, external exposure, and homegrown produce ingestion
C-14	Groundwater ingestion
Cl-36	Groundwater ingestion
I-129	Groundwater ingestion
Nb-94	External exposure
Np-237	Groundwater ingestion
Pu-238	Soil ingestion and homegrown produce ingestion
Pu-239	Soil ingestion and homegrown produce ingestion
Pu-240	Soil ingestion and homegrown produce ingestion
Sr-90	Homegrown produce ingestion
Tc-99	Groundwater ingestion and homegrown produce ingestion
U-233	Groundwater ingestion
U-234	Groundwater ingestion
U-235	Groundwater ingestion
U-236	Groundwater ingestion
U-238	Groundwater ingestion
Carbon tetrachloride	Inhalation and groundwater ingestion
Methylene chloride	Groundwater ingestion
Nitrates	Groundwater ingestion
Tetrachloroethylene	Groundwater ingestion and dermal exposure to contaminated water

2.5 Step 4. Identify Source Areas of Concern

Step 4 locates within the SDA the source of contamination, because both risks and remediation are location specific. The areas of contamination are then combined into discrete source areas to facilitate contaminant fate and transport modeling. This waste distribution will be conducted in the RI/BRA. As a point of reference, the ABRA divided the SDA into 13 discrete source areas. Eighteen source areas will be modeled in the RI/BRA and feasibility study. Tables 4 and 5 show how to present the source area definitions and where the contaminants are located with respect to the source areas.

Table 4. Sample template for source areas.

Source Area	Description
1	TBD
2	TBD
3	TBD
18	TBD

TBD = to be determined

Table 5. Sample template for contaminants of concern located in each source area.

Contaminant	Source Areas
Am-241	TBD
C-14	TBD
Cl-36	TBD
Tetrachloroethylene	TBD

TBD = to be determined

2.6 Step 5. Estimate the Quantity of Contaminants Released from Each Source Area

Step 5 estimates the quantity of contaminants already released and outside of the source area. The source area is defined as the waste zone, the underburden to the first basalt layer, and the overburden. This step is necessary because some of the waste has been disposed of over 50 years (disposal began in 1952) and releases continue to occur. Contaminants no longer in the source areas are largely unavailable for removal or treatment. Notable exceptions are the volatile organics and any radionuclides that might be in gaseous form (e.g., C-14). In the examples that follow, it is assumed that remedial action will begin in the Year 2010. The actual development of PRGs will use the date at which the remedial action is expected to begin.

The ABRA used the DUST-MS source-term model to calculate releases based on three types of release mechanisms: surface washoff, diffusion, and dissolution. These releases then were evaluated by the TETRAD model for subsurface fate and transport simulations and by DOSTOMAN to simulate biotic uptake. For this methodology, source-term modeling results from DUST-MS (in the RI/BRA) will be used to estimate the releases, and GWSCREEN instead of TETRAD will be used for the fate and transport simulations. The one-dimensional GWSCREEN model was selected for this initial screening to facilitate the execution of the many simulations within a short timeframe. It is expected the three-dimensional TETRAD model will be used for a limited set of final runs to verify the results. Also, to streamline the process, transport to the surface is not considered (i.e., no biotic modeling is performed). The results are scaled from changes in the release rates; however, this short period should have minimal effects on the results. The variable infiltration rates and the partition coefficients (K_ds) that will be used in the RI/BRA will be used in the methodology, and templates showing how the information is captured are presented in Tables 6 and 7.

Table 6. Sample template for source area infiltration rate.

Source Area	Description	Infiltration Rate (cm/year)
1	TBD	TBD
2	TBD	TBD
3	TBD	TBD
18	TBD	TBD

Table 7. Sample template for partition coefficients of the contaminants of concern.

Contaminant	K_d
Am-241	TBD
C-14	TBD
Cl-36	TBD
Tetrachloroethylene	TBD

2.7 Step 6. Estimate the Groundwater Risk from Released Contaminants

Step 6 takes releases from all of the source areas and calculates the peak groundwater concentration and residential groundwater ingestion risk for each of the groundwater COCs. Simulations are run using GWSCREEN and assume a reduced infiltration rate of 1 cm/year at the beginning of the planned remedial action and also assume no releases after remedial action begins. The reduced infiltration rate assumes that a simple native soil cap has been added to the source areas. These results can then be compared to maximum contaminant levels and the RAO to see whether a potential groundwater problem exists. This information is needed because remedial actions taken in the source areas will not affect contaminants that have migrated outside of the source area. The agencies will be required to make risk management decisions for contaminants outside of the waste zone if they pose unacceptable risk.

Three separate simulations were conducted to estimate whether contaminant levels outside the source area might pose an unacceptable groundwater health risk. These simulations are described in Section 3, and the results are discussed in Section 4. These results are preliminary. Refined results will be developed in the RI/BRA. Table 8 captures potential groundwater effects from released contaminants.

Table 8. Sample template for groundwater risk from released contaminants.

Groundwater Contaminants of Concern	Groundwater Risk from all Source Areas[a]
C-14	
Cl-36	Template
I-129	
Tetrachloroethylene	

a. Final risk estimates have not yet been calculated.

2.8 Step 7. Estimate Quantities of Contaminants Remaining in Source Areas

Step 7 quantifies remaining contaminants in each source area by subtracting the releases calculated in Step 5 from the original disposed of inventory. These remaining contaminants are those that are readily available for any selected remedial action and form the starting point for generating PRGs. Table 9 shows how to present the contaminant quantities and their locations.

2.9 Step 8. Estimate Risks for Exposure Routes of Concern

Step 8 estimates risks for exposure routes of concern from COCs remaining in the waste zone for each relevant source area. The route-specific risks from contaminants remaining in the waste zone will be calculated by using the RI/BRA source area infiltration rate and waste form release rate. This step has two parts. The first uses GWSCREEN to estimate groundwater route-specific risks from contaminants remaining in the waste zone. The second part computes surface route-specific risks from contaminants remaining in the waste zone by (1) using DUST-MS to calculate revised release rates and (2) scaling the results to estimate a corresponding surface route risk. This step must be done for all contaminants, source areas, and exposure routes of concern. Note that currently the DOSTOMAN program is not being run to streamline the screening process. DOSTOMAN modeling will be included for a limited set of final runs.

Table 9. Sample template for quantities of contaminants remaining in source areas.

Contaminant of Concern	Source Areas of Concern	Disposed of Mass (g)	Disposed of Activity (pCi)	Remaining Mass (g)	Remaining Activity (pCi)
Am-241	1				
	2				
	3				
	18				
C-14	1				
	2				
	3				
	18				
Cl-36	1				
	2				
	3				
	18				
Tetrachloroethylene	1				
	2				
	3				
	18				

2.10 Step 9. Calculate a Matrix of Risk Results

Step 9 calculates a matrix of risk results for a combination of four additional release rates from the waste form and three different infiltration rates for each COC and each exposure route of concern. Step 9 begins developing technology performance objectives for infiltration into the waste zone and releases from the waste form. First, for the exposure route of concern, the risk calculation in the previous step is repeated; however, this time, iterations on the infiltration rate and the release rate are evaluated. The first set of iterations increases the infiltration rate to the average annual precipitation for the SDA (i.e., 23 cm/year). The 23 cm/year assumes 100% of the annual precipitation infiltrates and is a reasonable upper bound for understanding how a remedial alternative will perform. For the other two infiltration iterations, the source-area-specific infiltration rate is modified to 1 cm/year (the undisturbed background infiltration rate) and 0.1 cm/year (infiltration rate used to simulate an INEEL CERCLA Disposal Facility [ICDF]-type cap), respectively. This range should bound the expected performance of the various remedial alternatives. The second set of iterations reduces the ABRA waste form release rate by factors of 10, 100, 1,000, and 10,000. This range should bound the expected performance of various remedial alternative technologies including in situ grouting and in situ vitrification. At the conclusion of this step, a 4 × 5 matrix of risk results is prepared for each COC for each exposure route of concern. Table 10 provides a sample template for one radionuclide (i.e., C-14) for the groundwater exposure ingestion route for one source area.

Table 10. Sample template for the technology performance-objective development matrix for C-14, for one source area, groundwater exposure route.

Technology Performance Objective Development				
Source area	1			
Contaminant of concern	C-14			
Exposure route of concern	Groundwater ingestion			
	Average Annual Precipitation for SDA = 23 cm/year	Source-Area-Specific Infiltration Rate from the RI/BRA	Undisturbed Background Infiltration Rate (1 cm/year)	Infiltration Rate Used to Simulate an ICDF-Type Cap (0.1 cm/year)
Base release rate from RI/BRA				
0.1 of the base release rate				
0.01 of the base release rate				
0.001 of the base release rate				
0.0001 of the base release rate				

Template

ICDF = INEEL CERCLA Disposal Facility
RI/BRA = remedial investigation and baseline risk assessment
SDA = Subsurface Disposal Area

For each source area, there will be other matrices like the one for C-14 for each of the COCs and for each exposure route of concern.

By reviewing the completed matrices, the acceptable combinations of infiltration rate and release rate will be clear. The acceptable combinations are those that give an exposure route risk result that will satisfy the RAOs.

This matrix development continues for the remaining source areas.

2.11 Step 10. Develop Preliminary Remediation Goals for the Source Areas

For certain types of exposure, the contaminant concentration is of interest rather than the flux to the media of concern. This is especially true for some surface route exposures. Step 10 in the methodology develops contaminant-specific, exposure-route-specific PRGs. While the U.S. Environmental Protection Agency has developed standard tools for deriving PRGs (EPA 1991), this methodology takes advantage of the site-specific risk work to be done in the RI/BRA. To show how this works, information is taken from the ABRA with the recognition that these values will change.

For the groundwater ingestion exposure route, the ABRA estimates the contaminant-specific, groundwater-ingestion risk for each source area. This example scales the initial source area contaminant concentration to 1E-06 (hazard quotient = 1) risk. For example, if the groundwater ingestion risk for Source Area 11 from C-14 (with a source area concentration of 611 pCi/g) is 1E-05, then the groundwater PRG for C-14 for Source Area 11 would be 61 pCi/g. These soil-to-groundwater PRGs are developed for each COC for each source area. Note that the methodology, when implemented, will scale the RI/BRA results to values that will satisfy the RAOs.

For surface route exposures, the ABRA treats the entire SDA as one source area. This example again scales the contaminant-specific results to a 1E-06 (i.e., hazard quotient = 1) risk. For example, if the residential homegrown produce ingestion risk from Sr-90 with an SDA concentration of 9.35 pCi/g is 1E-04, then the crop ingestion PRG would be 0.0935 pCi/g. The other three surface exposure route PRGs (i.e., soil ingestion, inhalation, and external exposure) are developed similarly. As mentioned previously, the methodology when implemented will scale the RI/BRA results to values that will satisfy the RAOs. A sample template for PRG development for one source area is shown in Table 11.

Table 11. Sample template of the preliminary remediation goal development matrix for one source area.

Contaminant of Concern	Groundwater Ingestion	Homegrown Produce Ingestion	External Exposure	Soil Ingestion	Inhalation
Am-241					
C-14					
Cl-36			Template		
Tetrachloroethylene					

2.12 Step 11. Compile Results by Source Area

Because any remediation will be done by source area, this step in the methodology compiles and highlights previous results by source area and contaminant. From this compilation, limiting PRGs and contaminants that drive the results are readily identified. The methodology evaluates the risk matrix for each COC developed in Step 9. Using that matrix, it is possible to identify the highest release rate that still provides an acceptable risk result. The result will be either (1) the base release rate from the RI/BRA or (2) one of the four fractional release rates. Similarly, from the matrix, it is possible to identify the highest infiltration rate that still provides an acceptable risk result. The result will be (1) the RI/BRA base infiltration rate, (2) the average annual precipitation for the SDA, (3) 1 cm/year, or (4) 0.1 cm/year.

Once all the contaminants have been evaluated, the limiting cases for the source area will be (1) the lowest of the highest acceptable release rates and (2) the lowest of the highest acceptable infiltration rates. Similarly, the methodology evaluates the PRG matrix developed in Step 10 for each contaminant and each source area and identifies the lowest PRGs. These results then can be compared with the quantity of contaminants remaining in the source area along with the contaminant quantity that has already left the source area (Step 6). A sample template for showing the summary results for one source area is provided in Table 12.

Table 12. Sample template of a technology performance objective and preliminary remediation goal summary table for one source area.

Contaminant of Concern	Highest Acceptable Release Rate	Highest Acceptable Infiltration Rate	Lowest Human-Health Preliminary Remediation Goal
Am-241			
C-14			
Cl-36		Template	
Tetrachloroethylene			

2.13 Step 12. Conduct a Combined Analysis for All Source Areas

Using results from each source area, this last step conducts a combined analysis to verify that RAOs are met. A cumulative residual risk analysis predicated on hypothetical risk management decisions for each source area will consider all source areas, contaminants, and exposure routes. After initial PRGs are identified using GWSCREEN, effectiveness of remedial alternatives will be evaluated in the feasibility study by using more robust models (i.e., DUST-MS and TETRAD) to evaluate residual risk and affirm that alternatives satisfy RAOs.

3. TEST CASES

Three different test cases were prepared to capture major features of the methodology and to uncover implementation problems. These problems are basic because data are insufficient or the methodology is too complicated or too costly to implement. Information used in the test cases is preliminary in nature and taken largely from the ABRA. The methodology, when implemented, will use approved values from the RI/BRA and other agency-approved documents. As such, the results of these test cases are not appropriate for any use.

Additionally, as discussed in Step 6, three simulations were performed as a quick groundwater risk check for contaminants that may have left the source area by the time remedial action begins.

3.1 Test Case 1—Carbon-14

The first test case (see Figure 4) addressed C-14. Carbon-14 was identified in the ABRA as a COC posing a peak risk of 6E-04 from the groundwater ingestion exposure route in the Year 2278. Other characteristics that made C-14 a good test case include the following:

- Fairly long half-life of 5,715 years
- Low K_d of 0.1 mL/g
- Presence in the SDA in several distinct waste forms with two different release mechanisms (i.e., surface washoff and dissolution).

3.2 Test Case 2—Strontium-90

The second test case (see Figure 5) addressed Sr-90. Strontium-90 was identified in the ABRA as posing a peak risk from ingestion of homegrown produce of 1E-04 in the Year 2110. Although Sr-90 has a relatively short half-life of 28.8 years, it does pose one of the highest ingestion risks for residential homegrown produce. The primary release mechanisms for the Sr-90 waste are dissolution and surface washoff. The Sr-90 waste is located throughout the SDA with the major locations being the low-level waste pits and trenches.

3.3 Test Case 3—Uranium-238

The third test case (see Figure 6) addressed U-238. Uranium-238 was identified in the ABRA as having the highest risk of any contaminant, posing a peak risk of 3E-03 from groundwater ingestion in the years after 3010. Uranium-238 has an extremely long half-life of almost 4.5 billion years, and approximately 350,000 kg of U-238 is buried throughout the SDA, with the major locations being Trenches 1-10, Pits 1 and 2, and Pad A. The major release mechanism for the U-238 waste forms is surface washoff. There is one change from the ABRA computations. This methodology uses a uranium solubility limit of approximately 1.0E-06 g/cm^3, while the ABRA applied a 5.98E-04-g/cm^3 solubility limit. This revised solubility limit represents the best estimate for acidity and redox conditions in the waste. The value to be used in the actual implementation of the methodology will be the one used in the final RI/BRA.

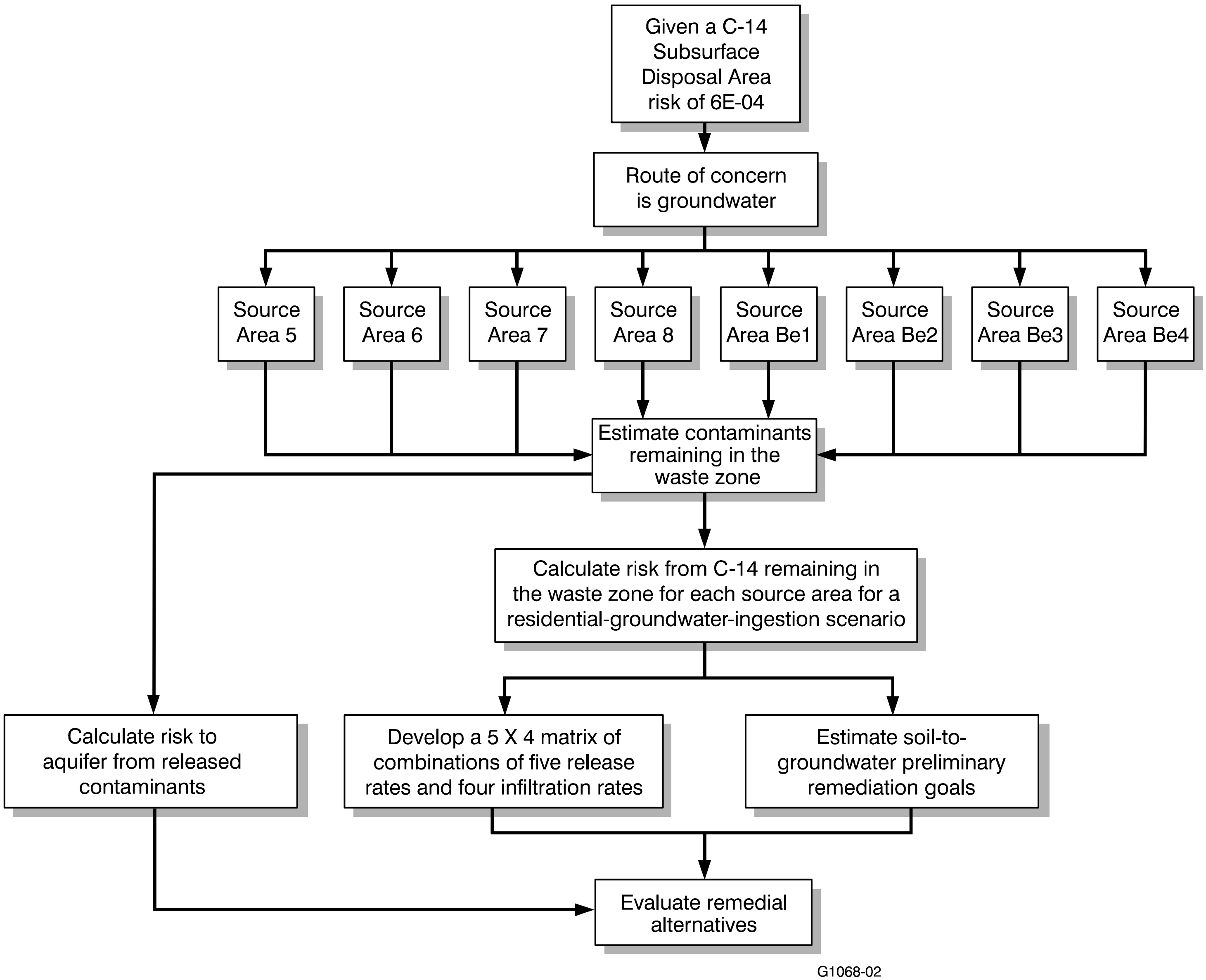

Figure 4. Carbon-14 development of human-health preliminary remediation goals.

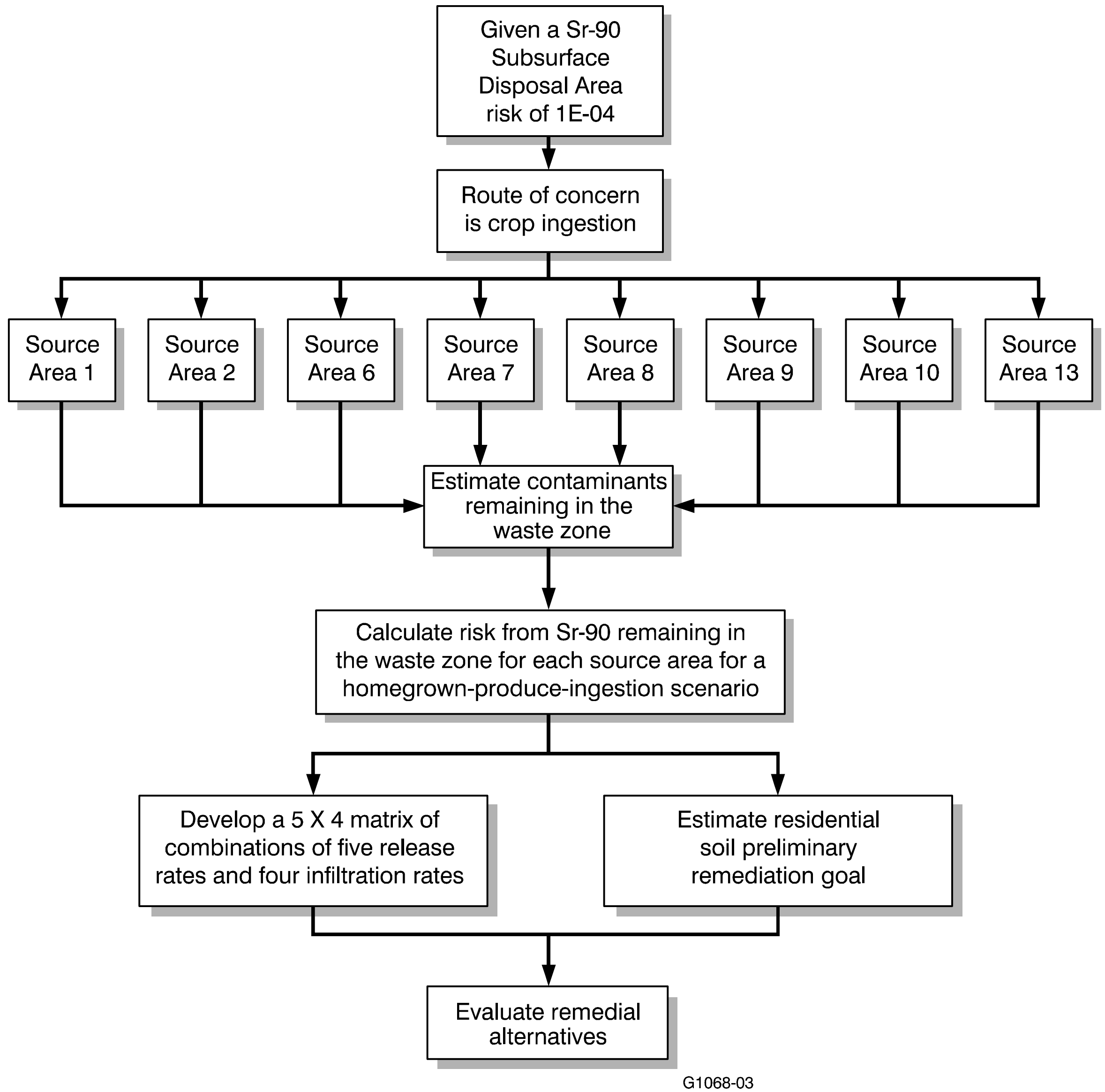

Figure 5. Strontium-90 technology performance objective development.

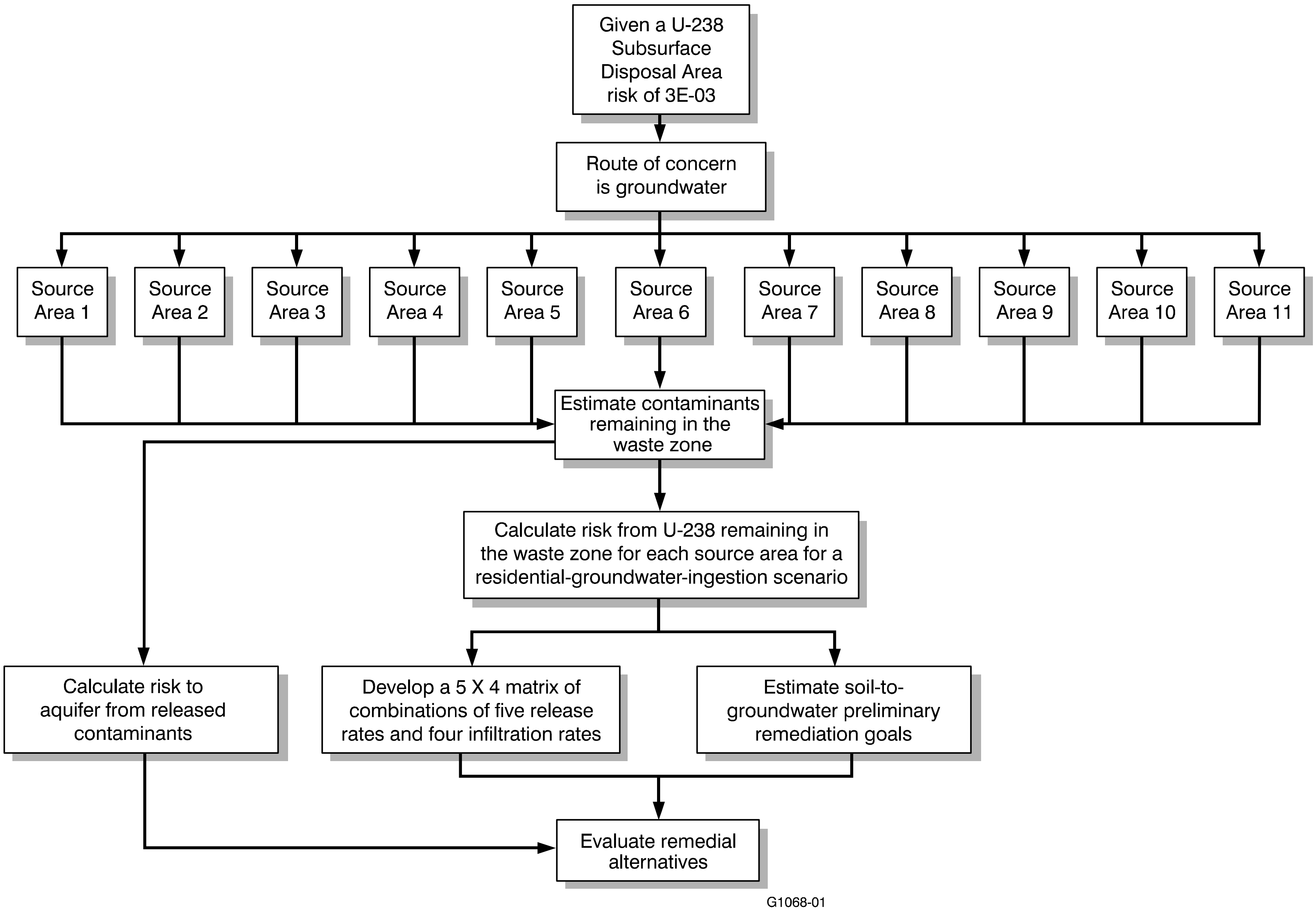

Figure 6. Uranium-238 development of human-health preliminary remediation goals.

3.4 Test Case 4—Groundwater Quick Look

The fourth test case consists of three simulations performed as a quick check of groundwater risk for contaminants that may have left the source area by the time remedial action begins.

The first simulation assumed 2 Ci of Tc-99 disposed of in the Year 1952 and calculated the fractional release by the Year 2010 for a range of K_ds (0-10,000). This test simulation using DUST-MS assumed no cap, a surface washoff release, and an infiltration rate of 5 cm/year.

The second simulation looked at U-238, a groundwater risk driver identified in the ABRA. This test simulation assumed that the entire SDA inventory of U-238 was buried in 1952, with an infiltration rate of 5 cm/year and a solubility limit of approximately 1.0E-06 g/cm^3.

The third simulation looked at C-14 and two types of release mechanisms: surface washoff and dissolution. Using GWSCREEN, this test simulation assumed no solubility limit and an infiltration rate of 10 cm/year. Potential vapor-phase partitioning was not assessed.

4. INTERPRETATION OF TEST CASE RESULTS

4.1 Test Case 1—Carbon-14

The first test case (see Figure 4) addressed C-14. Since the ABRA was prepared, locations of C-14 in the SDA have been refined. This test case used the refined distribution of C-14 (i.e., eight locations instead of the three used in the ABRA). These eight locations and quantities present in the waste zone in Year 2010 are as follows:

1. Source Area 5—Pre-1960 trenches = 49.39 Ci

2. Source Area 6—1960–1966 trenches = 55.26 Ci

3. Source Area 7—1967-1983 trenches = 69.75 Ci

4. Source Area 8—Low-level waste pit = 38.96 Ci

5. Source Area Be1—Beryllium disposals in Trench 58 = 39.08 Ci

6. Source Area Be2—Beryllium disposals in SVR 17 = 14.94 Ci

7. Source Area Be3—Beryllium disposals in SVR 20 = 11.42 Ci

8. Source Area Be4—Beryllium disposals in Trench 52 = 19.4 Ci.

Major sources for C-14[a] are listed below:

- Activation products from the Test Reactor Area (208 Ci, approximately 42%)

- Core structural pieces and related waste from the Naval Reactors Facility (107 Ci, approximately 21%)

- Beryllium waste from the Test Reactor Area (93 Ci, approximately 18%)

- Fuel end pieces from the Chemical Processing Plant (now called the Idaho Nuclear Technology and Engineering Center) (46 Ci, approximately 9%).

The simulations considered two types of release rates (i.e., surface washoff and corrosion). The surface washoff rate was represented by K_d, while the corrosion was represented by a fractional release rate. The base case for C-14 used a K_d of 0.1 mL/g. A 1.19E-05/year fractional release rate was used for the stainless steel waste forms and 2.65E-03/year for the beryllium blocks.

Table 13 shows the residential groundwater ingestion risk results of simulations for four infiltration rates and five release rates for each of the eight source areas. Infiltration rates are 23 cm/year (entire SDA average annual precipitation), source-area-specific infiltration rate assigned in the ABRA, 1 cm/year (undisturbed background infiltration rate), and 0.1 cm/year (infiltration rate used to simulate an ICDF-type cap). Release rates used are the ABRA base case, which then are reduced by a factor of 10,

a. Ongoing inventory validation indicates the C-14 generated by the Naval Reactors Facility should be increased to approximately 140 Ci, the C-14 generated by the Idaho Nuclear Technology Engineering Center should be reduced to approximately 2.6 Ci, and approximately 31.5 Ci should be attributed to Argonne National Laboratory-West.

100, 1,000, and 10,000. Result ranges have been highlighted to facilitate interpretation of the simulations. These highlighted results are from combinations of infiltration and release rates that would achieve a specific risk range for this contaminant and source area. For example, when evaluating Source Area 5 (pre-1960 trenches), the C-14 groundwater ingestion risk for the base infiltration rate of 4.9 cm/year is 1.1E-05, with base release rates of $K_d = 0.1$ and a fractional release rate of 1.19E-05/year. If the release rate is reduced by an order of magnitude, the risk drops approximately 40% to 4.8E-06. Reducing the release rate by yet another order of magnitude (i.e., a 100-fold from the original), the risk result is now 7.7E-07. This means that, if the infiltration rate remains the same, the release rate would have to be reduced by a factor of 100 to reduce the risk and order of magnitude.

Table 13. Carbon-14 test case—groundwater ingestion risk.

Source Area 5, 49.39 Ci					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	Infiltration Rates (cm/year) 23	4.9	1	0.1
0.1	1.19E-05	2.6E-05	1.1E-05	3.3E-06	1.0E-06
1	1.19E-06	1.7E-05	4.8E-06	8.5E-07	9.7E-08
10	1.19E-07	4.1E-06	7.7E-07	1.1E-07	1.0E-08
100	1.19E-08	4.8E-07	8.2E-08	1.2E-08	1.0E-09
1,000	1.19E-09	4.9E-08	8.3E-09	1.2E-09	1.0E-10
Peak time (years)		116-152	198-225	470	2,922-3,455
Source Area 6, 55.26 Ci					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	3.7	1	0.1
0.1	1.19E-05	6.7E-05	2.1E-05	6.7E-06	1.1E-06
1	1.19E-06	4.6E-05	9.5E-06	2.2E-06	1.8E-07
10	1.19E-07	1.1E-05	1.5E-06	3.0E-07	2.0E-08
100	1.19E-08	1.3E-06	1.6E-07	3.1E-08	2.1E-09
1,000	1.19E-09	1.4E-07	1.6E-08	3.1E-09	2.1E-10
Peak time (years)		113-152	209-251	470-471	2,922

Table 13. (continued).

Source Area 7, 69.75 Ci

Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	2.2	1	0.1
0.1	1.19E-05	5.974E-04	1.100E-04	4.926E-05	4.066E-06
1	1.19E-06	4.212E-04	5.144E-05	1.932E-05	1.147E-06
10	1.19E-07	1.051E-04	7.410E-06	2.654E-06	1.621E-07
100	1.19E-08	1.228E-05	7.789E-07	2.754E-07	1.668E-08
1,000	1.19E-09	1.248E-06	7.829E-08	2.764E-08	1.673E-09
Peak time (years)		113-152	280-310	469-470	2,893-3,178

Source Area 8, 38.96 Ci

Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	2.9	1	0.1
0.1	1.19E-05	1.9E-03	4.4E-04	1.5E-04	1.0E-05
1	1.19E-06	1.3E-03	2.2E-04	6.0E-05	2.7E-06
10	1.19E-07	3.3E-04	3.3E-05	8.3E-06	4.9E-07
100	1.19E-08	3.8E-05	3.5E-06	8.6E-07	5.0E-08
1,000	1.19E-09	3.9E-06	3.5E-07	8.6E-08	5.0E-09
Peak time (years)		113-152	234-286	458-470	2,893-3,178

Source Area Be1, 39.08 Ci

Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	2.0E-04	1.7E-04	9.2E-05	1.0E-05
2.65E-04	2.0E-05	1.7E-05	9.2E-06	4.6E-06
2.65E-05	2.0E-06	1.7E-06	9.2E-07	4.6E-07
2.65E-06	2.0E-07	1.7E-07	9.2E-08	4.6E-08
2.65E-07	2.0E-08	1.7E-08	9.2E-09	4.6E-09
Peak time (years)	154	180	550	3,049-3,455

Table 13. (continued).

Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
Source Area Be2, 14.94 Ci				
2.65E-03	7.6E-05	6.4E-05	3.5E-05	3.9E-06
2.65E-04	7.6E-06	6.4E-06	3.5E-06	1.7E-06
2.65E-05	7.6E-07	6.4E-07	3.5E-07	1.7E-07
2.65E-06	7.6E-08	6.4E-08	3.5E-08	1.7E-08
2.65E-07	7.6E-09	6.4E-09	3.5E-09	1.7E-09
Peak time (years)	154	180	550	3,049-3,455

Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
Source Area Be3, 11.42 Ci				
2.65E-03	5.8E-05	4.9E-05	2.7E-05	3.0E-06
2.65E-04	5.8E-06	4.9E-06	2.7E-06	1.3E-06
2.65E-05	5.8E-07	4.9E-07	2.7E-07	1.3E-07
2.65E-06	5.8E-08	4.9E-08	2.7E-08	1.3E-08
2.65E-07	5.8E-09	4.9E-09	2.7E-09	1.3E-09
Peak time (years)	154	180	550	3,049-3,455

Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1[f]
Source Area Be4, 19.4 Ci				
2.65E-03	9.860E-05	8.268E-05	4.583E-05	5.090E-06
2.65E-04	9.860E-06	8.268E-06	4.543E-06	2.259E-06
2.65E-05	9.860E-07	8.268E-07	4.543E-07	2.259E-07
2.65E-06	9.860E-08	8.268E-08	4.543E-08	2.259E-08
2.65E-07	9.860E-09	8.268E-09	4.543E-09	2.259E-09
Peak time (years)	154	180	550	3,049-3,455

Color key:

Red = risk greater than or equal to 1.0E-04

Blue = risk greater than or equal to 1.0E-05 and less than 1.0E-04

Yellow = risk greater than or equal to 1.0E-06 and less than 1.0E-05

Green = risk less than or equal to 1.0E-06.

Similarly, if the release rates stay the same, a factor of 4.9 reduction in the infiltration rate (from 4.9 to 1 cm/year) reduces the risk approximately 70% to 3.3E-06 from the base case. A further order of magnitude reduction in the infiltration rate (from 1 to 0.1 cm/year) yields a factor of 3 reduction in risk to 1.0E-06. These results indicate that, if the waste form stays the same, reducing the infiltration to 0.1 cm/year will produce a risk of 1.0E-06.

This same type of inspection can be conducted for each of the eight source areas. The results are highlighted in Table 13 to give combinations of infiltration and release rates that will achieve a specific risk range. In general, it appears an infiltration rate equal to or less than 0.1 cm/year will be required and at least a hundred-fold reduction in release rates to arrive at a risk from C-14 of 1E-06.

The next set of results shows the soil-to-groundwater PRGs. These goals are shown in Table 14. These PRGs were generated by scaling the groundwater ingestion risks from Table 13 to 1.0E-06. As an example, examining the results for Source Area 6 (i.e., 1960-1966 trenches), the PRG for the base case infiltration of 3.7 cm/year and the base case release rates is 45 pCi/g. This contrasts with the initial C-14 concentration of 943 pCi/g. If the infiltration is reduced from 3.7 to 1 cm/year, the PRG increases to 140 pCi/g. A further tenfold infiltration rate reduction gives a PRG of 940 pCi/g, which is just slightly less than the initial concentration of 943 pCi/g.

Table 14. Carbon-14 soil-to-groundwater preliminary remediation goals.

Source Area 5, 9.39 Ci					
		Infiltration Rates (cm/year)			
Release Rate (surface washoff K_d;)	Corrosion Fractional Release Rate	23	4.9	1	0.1
0.1	1.19E-05	2.6E+01	6.3E+01	2.0E+02	6.5E+02
1	1.19E-06	4.1E+01	1.4E+02		
10	1.19E-07	1.7E+02			
100	1.19E-08				
1,000	1.19E-09				
Carbon-14 Year 2010 concentration		6.76E+02 pCi/g			

Source Area 6, 55.26 Ci					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	3.7	1	0.1
0.1	1.19E-05	1.4E+01	4.5E+01	1.4E+02	9.4E+02
1	1.19E-06	2.1E+01	9.9E+01	4.3E+02	
10	1.19E-07	8.3E+01	6.2E+02		
100	1.19E-08	7.1E+02			
1,000	1.19E-09				
Carbon-14 Year 2010 concentration		9.43E+02 pCi/g			

Table 14. (continued).

Source Area 7, 69.75 Ci					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	2.2	1	0.1
0.1	1.19E-05	6.8E+01	3.7E+02	8.2E+02	1.0E+04
1	1.19E-06	9.6E+01	7.9E+02	2.1E+03	3.5E+04
10	1.19E-07	3.9E+02	5.5E+03	1.5E+04	
100	1.19E-08	3.3E+03			
1,000	1.19E-09	3.2E+04			
Carbon-14 Year 2010 concentration		4.06E+04 pCi/g			

Source Area 8, 38.96 Ci					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	2.9	1	0.1
0.1	1.19E-05	3.6E-01	1.5E+00	4.3E+00	6.6E+01
1	1.19E-06	5.1E-01	3.1E+00	1.1E+01	2.5E+02
10	1.19E-07	2.0E+00	2.0E+01	8.1E+01	
100	1.19E-08	1.7E+01	1.9E+02		
1,000	1.19E-09	1.7E+02			
Carbon-14 Year 2010 concentration		6.65E+02 pCi/g			

Source Area Be1, 39.08 Ci				
Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	8.3E+01	9.9E+01	1.8E+02	1.6E+03
2.65E-04	8.3E+02	9.9E+02	1.8E+03	3.6E+03
2.65E-05	8.3E+03	9.9E+03		
2.65E-06				
2.65E-07				
Carbon-14 Year 2010 concentration	1.66E+04 pCi/g			

Table 14. (continued).

Source Area Be2, 14.94 Ci

Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	8.3E+01	9.9E+01	1.8E+02	1.6E+03
2.65E-04	8.3E+02	9.9E+02	1.8E+03	3.6E+03
2.65E-05				
2.65E-06				
2.65E-07				
Carbon-14 Year 2010 concentration	6.33E+03 pCi/g			

Source Area Be3, 11.42 Ci

Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	8.3E+01	9.9E+01	1.8E+02	1.6E+03
2.65E-04	8.3E+02	9.9E+02	1.8E+03	3.6E+03
2.65E-05				
2.65E-06				
2.65E-07				
Carbon-14 Year 2010 concentration	4.84E+03 pCi/g			

Source Area Be4, 19.4 Ci

Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	8.3E+01	9.9E+01	1.8E+02	1.6E+03
2.65E-04	8.3E+02	9.9E+02	1.8E+03	3.6E+03
2.65E-05				
2.65E-06				
2.65E-07				
Carbon-14 Year 2010 concentration	8.22E+03 pCi/g			

Color key:

Yellow = risk greater than or equal to 1.0E-06 and less than 1.0E-05.

Similarly, if in the initial case the release rates are reduced by an order of magnitude, the PRG increases by a factor of 2–99 pCi/g. A further tenfold reduction in release rates yields a PRG of 620 pCi/g. Note that no PRGs are shown for further tenfold reductions in release rates because they exceed the original C-14 concentration.

This same type of inspection can be conducted for each of the eight source areas. These results indicate the allowable C-14 soil concentration for a given infiltration rate and a given set of release rates that will result in a 1.0E-06 groundwater ingestion risk or less. For those cases where the calculated PRG would be greater than the initial C-14 concentration, no results are specified.

One other way to view these results is shown in Table 15, which shows the calculation of a mass reduction percentage. Table 15 shows how much of the original mass of C-14 must be removed to result in a concentration equal to a soil-to-groundwater PRG of 1E-06. For instance, in the case of Source Area 5 and a base infiltration rate of 4.9 cm/year and with the base case release rates, 90.7% of the C-14 mass must be removed to achieve a risk reduction to 1.0E-06 for Source Area 5. For those cases with acceptable risk results, the reduction percentage is shown as zero.

Table 15. Carbon-14 test case—soil-to-groundwater preliminary remediation goal mass reduction percent to achieve risk of 1E-06.

Source Area 5, 49.39 Ci					
		Infiltration Rates (cm/year)			
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	4.9	1	0.1
0.1	1.19E-05	96.1%	90.7%	69.7%	3.3%
1	1.19E-06	94.0%	79.0%	0.0%	0.0%
10	1.19E-07	75.6%	0.0%	0.0%	0.0%
100	1.19E-08	0.0%	0.0%	0.0%	0.0%
1,000	1.19E-09	0.0%	0.0%	0.0%	0.0%
Source Area 6, 55.26 Ci					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	3.7	1	0.1
0.1	1.19E-05	98.5%	95.2%	85.1%	0.0%
1	1.19E-06	97.8%	89.5%	54.5%	0.0%
10	1.19E-07	91.2%	34.2%	0.0%	0.0%
100	1.19E-08	25.0%	0.0%	0.0%	0.0%
1,000	1.19E-09	0.0%	0.0%	0.0%	0.0%

Table 15. (continued).

Source Area 7, 69.75 Ci					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	2.2	1	0.1
0.1	1.19E-05	99.8%	99.1%	98.0%	75.4%
1	1.19E-06	99.8%	98.1%	94.8%	12.8%
10	1.19E-07	99.0%	86.5%	62.3%	0.0%
100	1.19E-08	91.9%	0.0%	0.0%	0.0%
1,000	1.19E-09	19.9%	0.0%	0.0%	0.0%

Source Area 8, 38.96 Ci					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	2.9	1	0.1
0.1	1.19E-05	99.9%	99.8%	99.3%	90.0%
1	1.19E-06	99.9%	99.5%	98.3%	63.1%
10	1.19E-07	99.7%	96.9%	87.9%	0.0%
100	1.19E-08	97.4%	71.2%	0.0%	0.0%
1,000	1.19E-09	74.3%	0.0%	0.0%	0.0%

Source Area Be1, 39.08 Ci				
Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	99.5%	99.4%	98.9%	90.2%
2.65E-04	95.0%	94.0%	89.1%	78.0%
2.65E-05	49.6%	39.9%	0.0%	0.0%
2.65E-06	0.0%	0.0%	0.0%	0.0%
2.65E-07	0.0%	0.0%	0.0%	0.0%

Source Area Be2, 14.94 Ci				
Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	98.7%	98.4%	97.2%	74.5%
2.65E-04	86.8%	84.3%	71.4%	42.5%
2.65E-05	0.0%	0.0%	0.0%	0.0%
2.65E-06	0.0%	0.0%	0.0%	0.0%
2.65E-07	0.0%	0.0%	0.0%	0.0%

Table 15. (continued).

Source Area Be3, 11.42 Ci				
Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	98.3%	97.9%	96.3%	66.6%
2.65E-04	82.8%	79.5%	62.6%	24.8%
2.65E-05	0.0%	0.0%	0.0%	0.0%
2.65E-06	0.0%	0.0%	0.0%	0.0%
2.65E-07	0.0%	0.0%	0.0%	0.0%

Source Area Be4, 19.4 Ci				
Release Rate = Beryllium Corrosion Fractional Release Rate	23	10	1	0.1
2.65E-03	99.0%	98.8%	97.8%	80.4%
2.65E-04	89.9%	87.9%	78.0%	55.7%
2.65E-05	0.0%	0.0%	0.0%	0.0%
2.65E-06	0.0%	0.0%	0.0%	0.0%
2.65E-07	0.0%	0.0%	0.0%	0.0%

NOTE: The preliminary remediation goal mass reduction percent is the percent of the Year 2010 C-14 concentration that must be removed to result in a 1E-06 groundwater ingestion risk.

Carbon-14 Source Area		Surface Area (cm^2)	Depth (cm)	Volume (cm^3)	Mass (g)
A5	Pre-1960 trenches	1.124E+08	4.332E+02	4.869E+10	7.304E+10
A6	1960-1966 trenches	9.016E+07	4.332E+02	3.906E+10	5.859E+10
A7	1967-1983 trenches	2.647E+06	4.332E+02	1.147E+09	1.720E+09
A8	Low-level waste pit	9.016E+07	4.332E+02	3.906E+10	5.859E+10
Be1	Beryllium disposals in Trench 58	2.647E+06	5.944E+02	1.573E+09	2.360E+09
Be2	Beryllium disposals in Soil Vault Row 17	2.647E+06	5.944E+02	1.573E+09	2.360E+09
Be3	Beryllium disposals in Soil Vault Row 20	2.647E+06	5.944E+02	1.573E+09	2.360E+09
Be4	Beryllium disposals in Trench 52	2.647E+06	5.944E+02	1.573E+09	2.360E+09

4.2 Test Case 2—Strontium-90

The second test case (see Figure 5) addressed Sr-90. Strontium-90 was identified in the ABRA as posing a peak risk from ingestion of homegrown produce of 1E-04 in the Year 2110. Although Sr-90 has a relatively short half-life of 28.8 years, it poses one of the highest ingestion risks for residential homegrown produce. The primary release mechanisms for Sr-90 waste are dissolution and surface washoff. The Sr-90 waste is located throughout the SDA with the major locations being the low-level waste pits and trenches. As was done for the ABRA, Sr-90 was assumed to be uniform across the entire SDA. The results of this test case are shown in Table 16.

Table 16. Strontium-90 test case—homegrown produce ingestion risk.

Source Area Subsurface Disposal Area, Strontium-90					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	Infiltration Rates (cm/year) 23	8.5—ABRA	1	0.1
60	1.0E-02	1.1E-04	1.0E-04	8.4E-05	7.2E-05
600	1.0E-03	1.1E-05	1.0E-05	8.4E-06	7.2E-06
600	1.0E-04	1.1E-06	1.0E-06	8.4E-07	7.2E-07
6,000	1.0E-05	1.1E-07	1.0E-07	8.4E-08	7.2E-08
60,000	1.0E-06	1.1E-08	1.0E-08	8.4E-09	7.2E-09
Strontium-90 Release Rates (Ci/year)					
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	8.5	1	0.1
60	1.0E-02	3.40E+02	3.12E+02	2.62E+02	2.23E+02
600	1.0E-03	3.41E+01	3.13E+01	2.63E+01	2.24E+01
600	1.0E-04	3.41E+00	3.13E+00	2.63E+00	2.24E+00
6,000	1.0E-05	3.41E-01	3.13E-01	2.63E-01	2.24E-01
60,000	1.0E-06	3.41E-02	3.13E-02	2.63E-02	2.24E-02

Color key:

Red = risk greater than or equal to 1.0E-04

Blue = risk greater than or equal to 1.0E-05 and less than 1.0E-04

Yellow = risk greater than or equal to 1.0E-06 and less than 1.0E-05

Green = risk less than or equal to 1.0E-06.

ABRA = Ancillary Basis for Risk Analysis (Holdren et al. 2002)

The base case risk as given in the ABRA is 1E-04. The table shows that reductions in the release rate are linear with the reductions in risk. This is because the methodology scales the results based on the release rate and does not take into account any nonlinear processes in the biotic uptake model. The feasibility study will evaluate the ability of each alternative to satisfy the RAOs and will assure the nonlinear processes are addressed. For changes in the infiltration rate, the risk results only vary slightly over the range from 23 to 0.1 cm/year, which equals a 30% reduction in risk for more than a twofold reduction in infiltration rate. In general, a two order-of-magnitude reduction in release rate is needed to achieve a risk of 1E-06 or less.

The next step in the process generates PRGs. Table 17 provides the results. Again, the PRGs were generated by scaling the ABRA risk results for the base infiltration and release rates. For the base infiltration rate of 8.5 cm/year, a base K_d of 60 mL/g, and a fractional release rate of 1.0E-02, the PRG for homegrown produce is 1.2E+05 pCi/g. This is in contrast to the SDA average Sr-90 concentration of 1.2E+07 pCi/g. A couple of simplifications make these results appear more disparate than they really are. These simplifications are that no losses are taken for either decay or biotic removal. However, this is just a screening step, and refinements, if deemed necessary, can be implemented later.

Table 17. Strontium-90 test case—soil (homegrown produce ingestion) preliminary remediation goals.

Source Area SDA, Strontium-90						
		Infiltration Rates (cm/year)				
Release Rate (surface washoff K_d)	Corrosion Fractional Release Rate	23	8.5—ABRA	1		0.1
60	1.0E-02	1.1E+05	1.2E+05	1.4E+05		1.7E+05
600	1.0E-03	1.1E+06	1.2E+06	1.4E+06		1.7E+06
600	1.0E-04	1.1E+07				
6,000	1.0E-05					
60,000	1.0E-06					
SDA (cm^2)		1.18E+09	—	—	—	—
Depth (cm)		3.00E+01	—	—	—	—
Volume (cm^3)		3.540E+10	—	—	—	—
Mass (g)		5.310E+10	—	—	—	—
Strontium-90 average concentration (pCi/g)		1.213E+07	—	—	—	—

Color key:

Yellow = risk less than or equal to 1E-06, no preliminary remediation goal calculated

ABRA = Ancillary Basis for Risk Analysis (Holdren et al. 2002)

SDA = Subsurface Disposal Area

4.3 Test Case 3—Uranium-238

The third test case (see Figure 6) addresses U-238. Uranium-238 was identified in the ABRA as having the highest risk of any contaminant, posing a peak risk of 3E-03 from groundwater ingestion in the years after 3010. Uranium-238 has an extremely long half-life of almost 4.5 billion years, and approximately 350,000 kg of U-238 is buried throughout the SDA, with the major locations being Trenches 1-10, Pits 1 and 2, and Pad A. The major release mechanism for the U-238 waste forms is surface washoff. There is one change from the ABRA computations. This methodology uses a uranium solubility limit of approximately 1.0E-06 g/cm^3, while the ABRA assumed a 5.98E-04 g/cm^3 solubility limit. This revised solubility limit represents the best estimate for the acidity and redox conditions assumed in the waste.

Table 18 shows the residential groundwater ingestion risk results of the simulations for four infiltration rates and five release rates for each of the 10 source areas. As with the results for C-14, the combinations of release rate and infiltration rate that result in specific groundwater ingestion risk ranges are highlighted. In general, the results indicate that if the source areas have an infiltration rate of 0.1 cm/year, the groundwater ingestion risk contribution from U-238 is below 1.0E-06. These results also indicate, depending on the infiltration rate, that a reduction in the release rate of at least 1,000—and in some cases 10,000—is needed to achieve a risk reduction to 1E-06.

Table 18. Uranium-238 test case—groundwater ingestion risk.

Source Area 1, 21.18 Ci				
	Infiltration Rates (cm/year)			
Release Rate (surface washoff K_d)	23	11.7—ABRA	1	0.1
6	7.4E-05	3.1E-05	1.7E-06	3.5E-08
60	7.4E-05	3.1E-05	1.7E-06	3.5E-08
600	7.4E-05	3.1E-05	1.7E-06	3.5E-08
6,000	1.1E-05	4.8E-06	2.7E-07	5.4E-09
60,000	1.1E-06	4.8E-07	2.7E-08	5.4E-10
Peak time (years)	9.70E+02	8.81E+03	1.30E+03	7.18E+04
Source Area 2, 18.1 Ci				
Release Rate (surface washoff K_d)	23	4.8—ABRA	1	0.1
6	6.3E-05	8.5E-06	1.5E-06	3.0E-08
60	6.3E-05	8.5E-06	1.5E-06	3.0E-08
600	6.3E-05	8.5E-06	1.5E-06	3.0E-08
6,000	9.7E-06	1.3E-06	2.3E-07	4.6E-09
60,000	9.8E-07	1.3E-07	2.3E-08	4.6E-10
Peak time (years)	9.70E+02	2.33E+03	8.81E+03	7.18E+04
Source Area 3, 3.735 Ci				
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1
6	2.6E-05	1.9E-06	5.9E-07	1.2E-08
60	2.6E-05	1.9E-06	5.9E-07	1.2E-08
600	2.0E-05	1.5E-06	4.7E-07	9.4E-09
6,000	2.0E-06	1.5E-07	4.7E-08	9.5E-10
60,000	2.0E-07	1.5E-08	4.7E-09	9.5E-11
Peak time (years)	9.70E+02	3.45E+03	8.81E+03	7.18E+04

Table 18. (continued).

Source Area 4, 10.84 Ci				
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1
6	6.8E-05	5.1E-06	1.6E-06	3.2E-08
60	6.8E-05	5.1E-06	1.6E-06	3.2E-08
600	5.7E-05	4.3E-06	1.4E-06	2.7E-08
6,000	5.8E-06	4.4E-07	1.4E-07	2.7E-09
60,000	5.8E-07	4.4E-08	1.4E-08	2.7E-10
Peak time (years)	9.70E+02	3.45E+03	8.81E+03	7.18E+04

Source Area 5, 8.322 Ci				
Release Rate (surface washoff K_d)	23	4.9—ABRA	1	0.1
6	6.6E-05	9.2E-06	1.5E-06	3.1E-08
60	6.6E-05	9.2E-06	1.5E-06	3.1E-08
600	4.4E-05	6.2E-06	1.0E-06	2.1E-08
6,000	4.5E-06	6.2E-07	1.0E-07	2.1E-09
60,000	4.5E-07	6.2E-08	1.0E-08	2.1E-10
Peak time (years)	9.70E+02	2.29E+03	8.81E+03	7.18E+04

Source Area 6, 4.184 Ci				
Release Rate (surface washoff K_d)	23	3.7—ABRA	1	0.1
6	3.4E-05	3.3E-06	7.8E-07	1.6E-08
60	3.4E-05	3.3E-06	7.8E-07	1.6E-08
600	2.2E-05	2.2E-06	5.2E-07	1.1E-08
6,000	2.3E-06	2.2E-07	5.3E-08	1.1E-09
60,000	2.3E-07	2.2E-08	5.3E-09	1.1E-10
Peak time (years)	9.70E+02	2.83E+03	8.81E+03	7.18E+04

Source Area 8, 0.1605 Ci				
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1
6	1.8E-05	2.1E-06	6.5E-07	1.3E-08
60	6.7E-06	5.8E-07	1.8E-07	4.0E-09
600	8.4E-07	6.4E-08	2.0E-08	4.1E-10
6,000	8.6E-08	6.5E-09	2.0E-09	4.1E-11
60,000	8.7E-09	6.5E-10	2.0E-10	4.1E-12

Table 18. (continued).

Peak time (years)	9.70E+02	3.45E+03	8.81E+03	7.18E+04
Source Area 9, 8.756 Ci				
Release Rate (surface washoff K_d)	23	2—ABRA	1	0.1
6	6.8E-05	3.4E-06	1.6E-06	3.2E-08
60	6.8E-05	3.4E-06	1.6E-06	3.2E-08
600	4.6E-05	2.3E-06	1.1E-06	2.2E-08
6,000	4.7E-06	2.4E-07	1.1E-07	2.2E-09
60,000	4.7E-07	2.4E-08	1.1E-08	2.2E-10
Peak time (years)	9.70E+02	4.72E+03	8.81E+03	7.18E+04
Source Area 10, 34.02 Ci				
Release Rate (surface washoff K_d)	23	0.6—ABRA	1	0.1
6	2.0E-05	4.6E-07	2.6E-07	9.2E-09
60	2.0E-05	4.6E-07	2.6E-07	9.2E-09
600	2.0E-05	4.6E-07	2.6E-07	9.2E-09
6,000	1.8E-05	4.3E-07	2.5E-07	8.6E-09
60,000	1.8E-06	4.3E-08	2.5E-08	8.6E-10
Peak time (years)	9.70E+02	1.43E+04	8.81E+03	7.18E+04
Source Area 11, 7.792 Ci				
Release Rate (surface washoff K_d)	23	3.7—ABRA	1	0.1
6	5.9E-05	5.9E-06	1.4E-06	2.8E-08
60	5.9E-05	5.9E-06	1.4E-06	2.8E-08
600	4.1E-05	4.1E-06	9.7E-07	2.0E-08
6,000	4.2E-06	4.2E-07	9.8E-08	2.0E-09
60,000	4.2E-07	4.2E-08	9.8E-09	2.0E-10
Peak time (years)	9.70E+02	2.83E+03	8.81E+03	7.18E+04

Color key:

Blue = risk greater than or equal to 1.0E-05 and less than 1.0E-04

Yellow = risk greater than or equal to 1.0E-06 and less than 1.0E-05

Green = risk less than or equal to 1.0E-06.

ABRA = Ancillary Basis for Risk Analysis (Holdren et al. 2002)

The next set of results shows the soil-to-groundwater PRGs. These goals are shown in Table 19. These PRGs were generated by scaling the groundwater ingestion risks from Table 18 to 1.0E-06. Also included for comparison purposes is the Year 2010 U-238 average concentration for each of the 10 source areas. Similar to the C-14 test case, evaluating one source area gives a good idea of how to interpret results for other source areas. For example, Source Area 1—with a base infiltration rate of 11.7 cm/year and a base release rate of K_d = 6—the soil-to-groundwater PRG is 9.4 pCi/g. This is in contrast to the Year 2010 average concentration of 290 pCi/g. Reducing the infiltration rate to 1 cm/year increases the soil-to-groundwater PRG to 170 pCi/g. A further tenfold reduction in infiltration rate to 0.1 cm/year indicates a risk less than 1E-06.

Table 19. Uranium-238 test case—soil-to-groundwater preliminary remediation goals.

Source Area 1, 21.2 Ci				
Release Rate (surface washoff K_d)	Infiltration Rates (cm/year) 23	11.7—ABRA	1	0.1
6	3.9E+00	9.4E+00	1.7E+02	
60	3.9E+00	9.4E+00	1.7E+02	
600	3.9E+00	9.4E+00	1.7E+02	
6,000	2.6E+01	6.1E+01		
60,000	2.5E+02			
U-238 Year 2010 concentration	2.90E+02 pCi/g			
Source Area 2, 18.1 Ci				
Release Rate (surface washoff K_d)	23	4.8—ABRA	1	0.1
6	4.6E+00	3.4E+01	2.0E+02	
60	4.6E+00	3.4E+01	2.0E+02	
600	4.6E+00	3.4E+01	2.0E+02	
6,000	3.0E+01	2.2E+02		
60,000				
U-238 Year 2010 concentration	2.91E+02 pCi/g			
Source Area 3, 3.735 Ci				
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1
6	5.8E+00	7.7E+01		
60	5.8E+00	7.7E+01		
600	7.6E+00	9.9E+01		
6,000	7.4E+01			

Table 19. (continued).

60,000				
U-238 Year 2010 concentration	1.48E+02 pCi/g			

Source Area 4, 10.84 Ci				
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1
6	2.4E+00	3.1E+01	1.0E+02	
60	2.4E+00	3.1E+01	1.0E+02	
600	2.8E+00	3.7E+01	1.2E+02	
6,000	2.8E+01			
60,000				
U-238 Year 2010 concentration	1.61E+02 pCi/g			

Source Area 5, 8.322 Ci				
Release Rate (surface washoff K_d)	23	4.9—ABRA	1	0.1
6	1.9E+00	1.4E+01	8.2E+01	
60	1.9E+00	1.4E+01	8.2E+01	
600	2.9E+00	2.1E+01	1.2E+02	
6,000	2.8E+01			
60,000				
U-238 Year 2010 concentration	1.26E+02 pCi/g			

Source Area 6, 4.184 Ci				
Release Rate (surface washoff K_d)	23	3.7—ABRA	1	0.1
6	3.8E+00	3.8E+01		
60	3.8E+00	3.8E+01		
600	5.7E+00	5.7E+01		
6,000	5.6E+01			
60,000				
U-238 Year 2010 concentration	1.26E+02 pCi/g			

Table 19. (continued).

Source Area 8, 0.1605 Ci				
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1
6	3.2E-01	2.8E+00		
60	8.7E-01			
600				
6,000				
60,000				
U-238 Year 2010 concentration	8.51E+00 pCi/g			

Source Area 9, 8.756 Ci				
Release Rate (surface washoff K_d)	23	2—ABRA	1	0.1
6	1.9E+00	3.8E+01	8.2E+01	
60	1.9E+00	3.8E+01	8.2E+01	
600	2.8E+00	5.6E+01	1.2E+02	
6,000	2.8E+01			
60,000				
U-238 Year 2010 concentration	3.19E+02 pCi/g			

Source Area 10, 34.02 Ci				
Release Rate (surface washoff K_d)	23	0.6—ABRA	1	0.1
6	8.9E+01			
60	8.9E+01			
600	8.9E+01			
6,000	9.6E+01			
60,000	9.6E+02			
U-238 Year 2010 concentration	5.05E+02 pCi/g			

Table 19. (continued).

Release Rate (surface washoff K_d)	23	3.7—ABRA	1	0.1
		Source Area 11, 7.792 Ci		
6	2.3E+00	2.3E+01	9.7E+01	
60	2.3E+00	2.3E+01	9.7E+01	
600	3.3E+00	3.2E+01		
6,000	3.2E+01			
60,000				
U-238 Year 2010 concentration	4.02E+02 pCi/g			

Yellow = risk less than or equal to 1.0E-06, no preliminary remediation goal calculated

ABRA = Ancillary Basis for Risk Analysis (Holdren et al. 2002)

As done in the C-14 test case, another way to view the PRG results is to evaluate the mass reduction percentage. Table 20 shows how much of the original inventory of U-238 must be removed to result in a concentration equal to a soil-to-groundwater PRG of 1E-06. Looking again at Source Area 1 and the base release rate and infiltration rate, 96.8% of the mass of U-238 must be removed to achieve the risk target of 1E-06. For those combinations of infiltration rates and release rates, with risk results less than or equal to 1E-06, the removal percentage is shown as zero.

Table 20. Uranium-238 test case—groundwater preliminary remediation goal mass reduction percent.

Release Rate (surface washoff K_d)	Infiltration Rates (cm/year)			
		Source Area 1		
	23	11.7—ABRA	1	0.1
6	98.6%	96.8%	41.9%	0.0%
60	98.6%	96.8%	41.9%	0.0%
600	98.6%	96.8%	41.9%	0.0%
6,000	91.2%	79.0%	0.0%	0.0%
60,000	12.4%	0.0%	0.0%	0.0%
		Source Area 2		
Release Rate (surface washoff K_d)	23	4.8—ABRA	1	0.1
6	98.4%	88.3%	31.9%	0.0%
60	98.4%	88.3%	31.9%	0.0%
600	98.4%	88.3%	31.9%	0.0%
6,000	89.7%	24.3%	0.0%	0.0%
60,000	0.0%	0.0%	0.0%	0.0%
		Source Area 3		
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1

Table 20. (continued).

6	96.1%	47.8%	0.0%	0.0%
60	96.1%	47.8%	0.0%	0.0%
600	94.9%	33.2%	0.0%	0.0%
6,000	50.2%	0.0%	0.0%	0.0%
60,000	0.0%	0.0%	0.0%	0.0%
		Source Area 4		
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1
6	98.5%	80.5%	37.0%	0.0%
60	98.5%	80.5%	37.0%	0.0%
600	98.2%	77.0%	25.9%	0.0%
6,000	82.9%	0.0%	0.0%	0.0%
60,000	0.0%	0.0%	0.0%	0.0%
		Source Area 5		
Release Rate (surface washoff K_d)	23	4.9—ABRA	1	0.1
6	98.5%	89.1%	35.3%	0.0%
60	98.5%	89.1%	35.3%	0.0%
600	97.7%	83.8%	3.5%	0.0%
6,000	77.7%	0.0%	0.0%	0.0%
60,000	0.0%	0.0%	0.0%	0.0%
		Source Area 6		
Release Rate (surface washoff K_d)	23	3.7—ABRA	1	0.1
6	97.0%	70.0%	0.0%	0.0%
60	97.0%	70.0%	0.0%	0.0%
600	95.5%	54.9%	0.0%	0.0%
6,000	55.6%	0.0%	0.0%	0.0%
60,000	0.0%	0.0%	0.0%	0.0%
		Source Area 8		
Release Rate (surface washoff K_d)	23	2.9—ABRA	1	0.1
6	94.5%	51.6%	0.0%	0.0%
60	85.1%	0.0%	0.0%	0.0%
600	0.0%	0.0%	0.0%	0.0%
6,000	0.0%	0.0%	0.0%	0.0%
60,000	0.0%	0.0%	0.0%	0.0%

Table 20. (continued).

Source Area 9				
Release Rate (surface washoff K_d)	23	2—ABRA	1	0.1
6	98.5%	70.6%	37.0%	0.0%
60	98.5%	70.6%	37.0%	0.0%
600	97.8%	57.1%	8.3%	0.0%
6,000	78.8%	0.0%	0.0%	0.0%
60,000	0.0%	0.0%	0.0%	0.0%
Source Area 10				
Release Rate (surface washoff K_d)	23	0.6—ABRA	1	0.1
6	94.9%	0.0%	0.0%	0.0%
60	94.9%	0.0%	0.0%	0.0%
600	94.9%	0.0%	0.0%	0.0%
6,000	94.5%	0.0%	0.0%	0.0%
60,000	45.5%	0.0%	0.0%	0.0%
Source Area 11				
Release Rate (surface washoff K_d)	23	3.7—ABRA	1	0.1
6	98.3%	83.0%	27.5%	0.0%
60	98.3%	83.0%	27.5%	0.0%
600	97.6%	75.8%	0.0%	0.0%
6,000	76.2%	0.0%	0.0%	0.0%
60,000	0.0%	0.0%	0.0%	0.0%

	Area (ft^2)	Volume (ft^3)	Volume (cm^3)	Mass (gm)
Source Area 1 = Trenches 1-10	120,960	1.72E+06	4.86E+10	7.29E+10
Source Area 2 = Pits 1 and 2	103,338	1.47E+06	4.15E+10	6.23E+10
Source Area 3 = Pit 3	41,830	5.94E+05	1.68E+10	2.52E+10
Source Area 4 = Pit 4	111,732	1.59E+06	4.49E+10	6.74E+10
Source Area 5 = Pit 5	108,754	1.54E+06	4.37E+10	6.56E+10
Source Area 6 = Pit 6	54,984	7.81E+05	2.21E+10	3.31E+10
Source Area 8 = Pit 9	31,294	4.44E+05	1.26E+10	1.89E+10
Source Area 9 = Pit 10	45,541	6.47E+05	1.83E+10	2.75E+10
Source Area 10 = Pad A	111,732	1.59E+06	4.49E+10	6.74E+10
Source Area 11 = Low-Level Waste Pits 17-20	32,160	4.57E+05	1.29E+10	1.94E+10

Uranium-238 Only	Original Inventory (Ci)	Inventory at Year 2010 (Ci)	Inventory at Year 2010 (pCi)	Concentration at Year 2010 (pCi/g)
A1	2.121E+01	2.118E+01	2.12E+13	2.90E+02

Table 20. (continued).

A2	1.812E+01	1.810E+01	1.81E+13	2.91E+02
A3	3.739E+00	3.735E+00	3.74E+12	1.48E+02
A4	1.085E+01	1.084E+01	1.08E+13	1.61E+02
A5	8.339E+00	8.322E+00	8.32E+12	1.27E+02
A6	4.191E+00	4.184E+00	4.18E+12	1.26E+02
A7	0.000E+00	0.000E+00	0.00E+00	0.00E+00
A8	1.629E-01	1.605E-01	1.61E+11	8.51E+00
A9	8.766E+00	8.756E+00	8.76E+12	3.19E+02
A10	3.403E+01	3.402E+01	3.40E+13	5.05E+02
A11	7.803E+00	7.792E+00	7.79E+12	4.02E+02
A12	0.000E+00	0.000E+00	0.00E+00	0.00E+00
A13	0.000E+00	0.000E+00	0.00E+00	0.00E+00

Notes:

The preliminary remediation goal mass reduction percentage is the percent of the Year 2010 uranium concentration that must be removed to result in a 1E-06 risk.

Uranium solubility ~1.0E-06 g/cm^3.

ABRA = Ancillary Basis for Risk Analysis (Holdren et al. 2002)

4.4 Test Case 4—Groundwater Quick Look

The first simulation assumed 2 Ci of Tc-99 disposed of in the Year 1952 and calculated the fractional release by the Year 2010 for a range of K_ds (0-10,000). This simulation using DUST-MS assumed no cap, a surface washoff release, and an infiltration rate of 5 cm/year. The results are shown in Table 21. These results show that those contaminants with a K_d of 1 or greater would have fractional releases of less than 0.6% after 58 years. A contaminant with a K_d of 10 has a release fraction of only 0.1%. This information can be used to screen out potential COCs.

Table 21. Quick check of the groundwater risk from technetium-99.

Technetium-99 (Run in DUST-MS)	Comparing Fractional Release for a Range of K_ds Infiltration Rate = 5 cm/year (assuming no cap) 1952 Activity (Ci) = 2	
K_d	2010 Activity (Ci)	Fraction Released by 2010 (Ci)
0	2.00E+00	1.00E+00
1	1.15E-02	5.74E-03
10	2.06E-03	1.03E-03
100	2.21E-04	1.10E-04
1,000	2.22E-05	1.11E-05
10,000	2.22E-06	1.11E-06

The second simulation looked at U-238, one of the major groundwater risk drivers in the ABRA. This simulation assumed that the entire SDA inventory of U-238 was buried in 1952, with an infiltration rate of 5 cm/year and a solubility limit of approximately 1.0E-06 g/cm^3. These results are shown in Table 22. After 58 years, the quantity of U-238 released would result in a peak groundwater residential ingestion risk of 2E-06.

Table 22. Quick check of the groundwater risk from uranium-238.

Uranium-238	Comparing 10,000-Year Release with Stopping Release at Year 2010		
(Run in GWSCREEN)	Infiltration Rate = 5 cm/year Assumed Solubility Limit = Approximately 1.0E-06 g/cm^3 Uranium-238 Release for Entire Subsurface Disposal Area		

Scenario	Release Time (years)	Peak Concentration (pCi/L)	Peak Risk
Base case (no action)	10,000	3.953E+01	5.312E-05
Stop release at Year 2010	58	1.465E+00	1.960E-06

The third simulation analyzed C-14 and two types of release mechanisms: surface washoff and dissolution. Using GWSCREEN, this simulation assumed no solubility limit and an infiltration rate of 10 cm/year. The results are shown in Table 23. These results show that 58 years of C-14 releases would result in a peak groundwater ingestion risk of 7.9E-05. It is premature to draw any specific conclusions because this is a simplified examination and includes no evaluation of gaseous releases of C-14; however, it indicates that a closer examination is warranted.

Table 23. Quick check of groundwater risk from carbon-14.

Carbon-14	Comparing 10,000-Year Release with Stopping Release at Year 2010		
(Run in GWSCREEN)	Infiltration Rate = 10 cm/year Assumed No Solubility Limit Carbon-14 Release for Source Areas A5-A8 and Be1-Be4		

Scenario	Release Time (years)	Peak Concentration (pCi/L)	Peak Risk
Base case (no action)	10,000	2.633E+03	8.370E-05
Stop release at Year 2010	58	2.511E+03	7.916E-05

5. SUMMARY

The methodology in this report provides a straightforward, 12-step process for development of PRGs for OU 7-13/14. These PRGs will be used for detailed and comparative analysis of remedial alternatives in the feasibility study. The methodology builds on both previous risk evaluations (e.g., the ABRA and the Second Revision to the Scope of Work) as well as information that will be generated from the RI/BRA. Because of the large number of computations that are expected based on the many COCs (approximately 20), multiple exposure routes, and numerous source areas, the methodology uses simplified computational approaches to calculate PRGs as either risk-based concentrations or technology performance objectives. The methodology acknowledges that more robust modeling is expected for a limited set of final conditions to verify the results. The methodology then presents the results in an easily understood matrix format for decision-makers and other interested parties. Test cases were run to demonstrate the major features of the methodology and to uncover any implementation problems.

6. REFERENCES

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